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(19) JAPANESE PATENT OFFICE

PATENT ABSTRACTS OF JAPAN

(11) Publication number: **04187843 A**

(43) Date of publication of application: **06.07.92**

(51) Int. Cl **F02D 41/14** **F02D 45/00**

(21) Application number: **02315800**

(22) Date of filing: **22.11.90**

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INAGAKI HIROSHI
NASU MASAHIRO

(54) FUEL INJECTION QUANTITY CONTROLLER FOR INTERNAL COMBUSTION ENGINE

(57) Abstract:

PURPOSE: To perform a stable control by determining a proper fuel injection quantity in corresponding relation to the operational state of an internal combustion engine, and correcting the fuel injection quantity in a manner to follow a change of this engine with time.

CONSTITUTION: A fuel injection quantity calculation means 103 determines fuel quantity injected from an injector 104, on the basis of the calculation result of a reference goal cylinder injection of fuel calculation means 102. The injector 104 injects fuel into a suction pipe near a suction valve on the basis of the calculation result of the calculation means 103. A fuel behavior simulation means 105 calculates an estimated cylinder injection of fuel on the basis of a simulation model representing dynamic behaviors of fuel in the vicinity of an injector of each air cylinder. A fuel injection quantity correction means 106 corrects the fuel injection quantity determined by the calculation means 103, on the basis of the output of an air-fuel sensor 100 and the calculation result of the simulation means 105. This enables stable maintenance of control.

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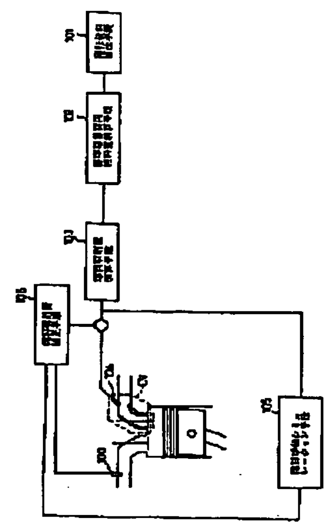

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AIMS

) [Claim(s)]
aim 1] It is based on the simulation model which expresses the dynamic behavior of fuel [near the injector of each inder] in the fuel-injection control unit characterized by providing the following. A fuel behavior simulation means ;alculate the fuel quantity in an anticipation cylinder which was probably poured in into each cylinder (105), A cific state detection means to detect that the operational status of an internal combustion engine is in specific ;rational status (107), A parameter-identification means to identify the parameter contained in the aforementioned l behavior simulation means (105) when it is detected by this specific state detection means that an internal nbustion engine is in a specific state (108), When it is detected by the aforementioned specific state detection means 7) that an internal combustion engine is not in a specific state It is based on the output of the aforementioned air-fuel-o sensor (100), and the fuel quantity in an anticipation cylinder calculated by the fuel behavior simulation means 5) using the identified parameter by this parameter-identification means (108). The fuel-injection control unit ıracterized by including an amendment fuel-oil-consumption amendment means (106) for the fuel quantity ermined by the aforementioned fuel-oil-consumption operation means (103) The air-fuel ratio sensor which is talled in the exhaust pipe of an internal combustion engine, and detects the air-fuel ratio of exhaust gas (100) An ;rational status detection means to detect the operational status of internal combustion engines other than an air-fuel .o (101), exhaust gas predetermined from the output of this air-fuel ratio sensor (100), and the amount of operational ;us detected with this operational status detection means (101) -- with a fuel quantity operation means (102) in a :eria target cylinder to calculate the fuel quantity which should be injected into each cylinder, in order to acquire a ıracter Based on the result of an operation of this fuel quantity operation means (102) in a criteria target cylinder, the erse model showing the dynamic behavior of fuel [near the injector of each cylinder] of a simulation model is used. ɜ injector which injects fuel in the style of [near the inlet valve] an inlet pipe based on the result of an operation of a l-oil-consumption operation means (103) to determine the fuel quantity which should be injected from an injector, l this fuel-oil-consumption operation means (103) (104)

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:TAILED DESCRIPTION

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etailed Description of the Invention]
dustrial Application]
s invention relates to the control unit of the fuel oil consumption of an internal combustion engine, and relates to the ntrol unit which determines fuel oil consumption based on the fuel behavior model showing the dynamic behavior of : fuel near the injector attached in the inlet pipe of an internal combustion engine in more detail.
escription of the Prior Art]
a method of controlling the fuel quantity which should be injected from the injector of an internal combustion gine, these people proposed the injection fuel control system which used the precise SHIMYURESHO model owing the dynamic behavior of the fuel near the injector installed in the inlet pipe of an internal combustion engine fer to JP,1-200040,A official report).
e simulation model which makes a state variable the fuel quantity fw adhering to the inlet-pipe internal surface in an agination closed space near the injector (control volume) and fuel quantity fv which evaporates in this closed space in s method is built. Since feedback control of the fuel oil consumption from an injector is carried out based on the ove-mentioned state variable so that the fuel quantity which actually flowed in the cylinder from the output of the air-el ratio sensor formed in the flueway may be detected and the value may be in agreement with desired value, An air-el ratio predetermined in a high precision is maintainable. However, this method is the so-called feedback control, i.e., : control which the exhaust air air-fuel ratio of an internal combustion engine is detected, begins, and becomes rrectable [fuel oil consumption], generally had the fault that control speed was slow, and when operational status anged rapidly, it had the fault that the precision of control fell.
order to cancel this fault, these people have proposed what controls an internal combustion engine by the control unit iich performs the control operation in the relation between the dynamic characteristics of an internal combustion gine, and a reverse property from the inflow fuel quantity in a target cylinder which becomes settled beforehand cording to the operational status of an internal combustion engine (Japanese Patent Application No. 2-193806).
roblem(s) to be Solved by the Invention]
owever, although the parameter of a control unit needs to describe correctly the model which has the relation between : dynamic characteristics of an internal combustion engine, and a reverse property if it is in the control unit which ed the reverse model, it is difficult to get to know a parameter exact for dispersion in the manufacture process of an ernal combustion engine, or aging, and there is a possibility that the error of this parameter may become a factor and ntrol may become unstable.
s invention is made in view of the above-mentioned trouble, and while corresponding to the operational status of an ernal combustion engine promptly and determining suitable fuel oil consumption, it aims at following a change of an ernal combustion engine with time, and offering the fuel-injection control unit of an amendment internal combustion gine for fuel oil consumption.
he means for solving a technical problem]
though the basic composition of the fuel-oil-consumption control unit of such an internal combustion engine is shown a view 1, it is constituted as follows.
mely, the air-fuel ratio sensor 100 which is installed in the exhaust pipe of an internal combustion engine, and detects : air-fuel ratio of exhaust gas, An operational status detection means 101 to detect the operational status of internal mbustion engines other than an air-fuel ratio, exhaust gas predetermined from the output of the air-fuel ratio sensor 0, and the amount of operational status detected with the operational status detection means 101 -- with a fuel antity operation means 102 in a criteria target cylinder to calculate the fuel quantity which should be injected into ch cylinder, in order to acquire a character A fuel-oil-consumption operation means 103 to determine the fuel quantity iich should be injected from an injector using the reverse model of a simulation model which expresses the dynamic

ıavior of fuel [near the injector of each cylinder] based on the result of an operation of the fuel quantity operation :ans 102 in a criteria target cylinder, The injector 104 which injects fuel in the style of [near the inlet valve] an inlet ıe based on the result of an operation of the fuel-oil-consumption operation means 103, A fuel behavior simulation :ans 105 to calculate the fuel quantity in an anticipation cylinder which was probably poured in into each cylinder sed on the simulation model showing the dynamic behavior of fuel [near the injector of each cylinder], A specific te detection means 107 to detect that the operational status of an internal combustion engine is in specific operational tus, A parameter-identification means 108 to identify the parameter contained in the fuel behavior simulation means 5 when it is detected by the specific state detection means that an internal combustion engine is in a specific state, e identified parameter according to the output and the parameter-identification means 108 of the air-fuel-ratio sensor 0 for it being detected by the specific state detection means 107 that an internal combustion engine is not in a specific te, and cooking is used. by the fuel behavior simulation means 105 With the amendment fuel-oil-consumption ıendment means 106, shell composition of the fuel quantity determined by the fuel-oil-consumption operation means 3 based on the calculated fuel quantity in an anticipation cylinder is carried out.

ınction]

us, in the fuel-oil-consumption control unit of the constituted internal combustion engine, while the suitable fuel oil ısumption for controlling the air-fuel ratio of exhaust gas by the reverse model of fuel dynamic characteristics to a :determined value is defined, fuel oil consumption is amended according to change of the property of an internal mbustion engine, and control is maintained stably.

xample]

ı Composition of an example A view 2 is drawing showing one example of the fuel-oil-consumption control unit of : internal combustion engine concerning this invention. In the view 2, the air flow meter 3 is installed in the ıalation-of-air path 2 of an internal combustion engine 1. An air flow meter 3 outputs the electrical signal which is a vice for measuring the air content which an internal combustion engine inhales, and is proportional to the volumetric ·w rate of inhalation air. This electrical signal is supplied to A/D converter 1001 of a control circuit 10.

.e degree sensor 6 of crank angle which converts into the degree sensor 5 of crank angle and the degree of crank angle ıich convert into the degree of crank angle and output a pulse signal every 720 degrees, and outputs a pulse every 30 grees is attached in the distributor 4. The pulse output of the degree sensor of crank angle is supplied to the ɔut/output interface 1002 of a control circuit 10.

ɔreover, from an exhaust manifold 11, the air-fuel ratio sensor 14 is installed in the down-stream exhaust pipe 13, the ltage according to the oxygen density in exhaust gas is outputted to it, and A/D converter 1001 is supplied.

control circuit 10 consists of for example, microcomputer systems, and contains A/D converter 1001, an input/output :erface 1002, CPU1003, ROM1004 and RAM1005, backup RAM 1006, and clock generation circuit 1007 grade.

ɔreover, the idle switch 16 for full open detecting [a throttle valve 15] whether it is no is formed in the throttle valve currently installed in the inhalation-of-air path 2, and this output is inputted into a control circuit 10 through an ɔut/output interface 1002.

oreover, in a control circuit 10, the down counter 1008, a flip-flop 1009, and the drive circuit 1010 are for controlling injector 7. That is, if fuel oil consumption calculates, the result of an operation will be set as the down counter 1008, d a flip-flop 1009 will also be simultaneously made into a set state.

; a result, the drive circuit 1010 energizes an injector 7.

hen the down counter 1008 starts counting of a clock pulse (not shown) and the value of the down counter 1008 comes zero, a flip-flop 1009 is reset and the drive circuit 1010 stops energization of a fuel injection valve.

ıat is, an injector 7 is energized only for the period calculated by fuel-oil-consumption control means, and the fuel cording to the result of an operation is supplied to each cylinder of an internal combustion engine 1.

) Design of a fuel-oil-consumption control unit The point which should be taken into consideration since control ecision constitutes the control unit which can perform stable high and control is as follows.

ıat is, all the fuel injected from the injector 7 is not poured in into a cylinder, but adheres to an inlet-pipe wall surface part.

ır this reason, even if it determines the injection quantity from an injector 7 that the air-fuel ratio of exhaust gas will rve as a predetermined value, a predetermined air-fuel ratio does not become.

ɔreover, that the dynamic characteristics of an internal combustion engine is with time or fuel -- it changes with ange of a character

ɜ above-mentioned point -- taking into consideration -- the dynamic characteristics of the fuel near the inlet valve -- cing into consideration -- fuel oil consumption -- determining -- change of dynamic characteristics -- detecting -- fuel l consumption -- an amendment -- a control unit is constituted like

Construction of the dynamic model (internal model) of fuel In order to obtain the mass balance of the fuel near the

ector, the imagination control volume valve flow coefficient near [as shown in a view 3] the injector is considered.
s k about the index showing the predetermined degree of crank angle (cycle). It is fi (k) about the fuel flow which ws into the predetermined degree k of crank angle (cycle) at valve flow coefficient.
s fw (k) about the fuel quantity which has adhered to the wall surface at the predetermined degree k of crank angle cle).
s fc (k) about the fuel flow which valve flow coefficient ****** to the predetermined degree k of crank angle (cycle).

s R about the rate which adheres to a wall surface among the inflow fuel flow fi (k). It is P about the rate which nains on a wall surface among the wall surface adhesion fuel quantity fw (k). deltaf, then the following formula are terialized in the error accompanying modeling.
(k+1) =P-fw (k)
-fi(k)-deltaf (1)
(k) = (1-P), fw (k)
1-R) -fi(k)+deltaf (2)
addition, (2) formulas constitute the fuel behavior simulation means 105 of a view 1.
Construction of the control system by the internal model and the reverse model A view 4 shows the basic nposition of the adaptive control system constituted using the internal model and the control unit.
s G about the equivalent transfer function of a control unit. It is H about the equivalent transfer function of an internal del. It is P about the equivalent transfer function of an actual internal combustion engine. It is fcro about the fuel antity in a criteria target cylinder. It is fcr about the fuel quantity in a target cylinder. It is fc about the actual charge of inder internal combustion. It is fcm about the fuel quantity in a cylinder calculated from the internal model. If the or of the actual fuel quantity fc in a cylinder and

$$fc = \frac{GP}{1-GH+GP} fcr \qquad (3)$$

$$f = \frac{fc - GHfcro}{1-GH} \qquad (4)$$

******. Therefore, it is from (3) formulas. HG=1 (5)
come out and it is (i.e., if a control unit is the reverse model of an internal model) fcro=fc (6)
s not based on the dynamic characteristics of a next door and an internal combustion engine, but the fuel quantity fc a cylinder becomes equal to the fuel quantity fcro in a criteria target cylinder.
oreover, when an error arises from a ** (4) formula between fc and fcro at the time of HG=1, a bird clapper turns out t control is unstable with the value of deltaf having become infinite and having mentioned above.
at is, if the control system shown in the 4th view is constituted, it will become possible to control the air-fuel ratio nbda of exhaust gas to target air-fuel ratio lambdar.
Operation of the fuel quantity fcro in a criteria target cylinder The fuel quantity fcro in a criteria target cylinder which ould be injected into each cylinder can calculate lambdar and an inhalation air content for a predetermined exhaust s air-fuel ratio from mc (k), then the following formula.
ro=lambda r-mc (k) (7)
e air flow rate mc (k) which flows into each cylinder here can be calculated by which the following method.
Compute by the ****** (8) formula.
(k) = (beta1 and Ne-Pm-beta 2, Ne) / Ti (8)
owever, Ne= internal combustion engine rotational frequency Pm= pressure-of-induction-pipe force Ti= intake-air nperature A basic inhalation air content is calculated from the map which makes a parameter beta and alpha= onstant b) MAP Pm and the internal combustion engine rotational frequency Ne, it amends with an intake-air nperature Ti, and mc (k) is calculated.
) Presume from the detection value of an air flow meter 3.
at is, a ** (7) formula and the above (a), (b) or, and (c) constitutes a part of fuel quantity operation means (102) in a teria target cylinder of a view 1.
) Construction of a feedforward control system It sets to the control system shown in a view 4, and is amendment fuel antity. deltaf=fc(k)-fcm (k) (9)
owever, although it becomes the fuel quantity in a model cylinder computed from the interior model of fcm=, since the el quantity fc in a cylinder (k) is directly immeasurable, it will ask according to an operation from Output lambda and

inhalation air content mc (k) of the air-fuel ratio sensor 14.
wever, since the flow delay of exhaust gas and detection delay peculiar to a sensor are included in measurement of an ·fuel ratio lambda, it becomes fc!=fcro, and a ** (9) formula becomes unstable so that clearly also from (4) formulas.
order to remove this trouble, these people have proposed the control unit which determines the amendment fuel antity which carries out feedforward control from the amount of operational status of an internal combustion engine panese Patent Application No. 1-54420).
refore, this invention -- also setting -- for example, delta f=delta o-fw -- (k {Pm(k)-Pm (k-1)})
wever, deltao= proportionality coefficient (10)
hall carry out and the amendment fuel quantity which carries out feedforward shall be determined.
at is, the remaining portion of the fuel quantity operation means (102) in a criteria target cylinder of the 1st view nsists of ** (10) formulas.
erefore, fuel quantity fcr in a target cylinder Fcr=fcro+deltaf (11)
s alike and, therefore, calculates.
Determination of fuel oil consumption The basic fuel flow fio (k) which should be injected from an injector 7 if fw which becomes settled from (1) formula is used is fio[from (2) formulas] (k) ={fcr- (1-P) and fw (k)}/(1-R). (12) can ask by carrying out.
at is, (12) formulas constitute the fuel-oil-consumption operation means 103 of a view 1.
Amendment of fuel oil consumption Fuel quantity actually poured in into a cylinder Fi=fio+deltaf (13)
en, the following formula is materialized.
tafc(k) = P-delta fc (k-1)
1-R) -deltafi (k-d +1)
R-P) -deltafi (k-d) (14)
s here. y(k) =deltafc (k)
:) =deltafi (k-d)
:) =y(k)-(1-R) -u (k)
Po+deltaP R=Ro+deltaR Po and Ro obtain the steady-state value, then the following formula of each parameter.
:+1) =Po-x (k)
Ro-(1-Po) -u (k)
'1 (15)
:) =x(k)+ (1-Ro) and u(k)+w2 (16)
and w2 are the function of delta P and delta R here. xs and us shall satisfy the following formula further.
=Po-xs+Ro -(1-Po)- us+w1 (17)
=xs+ (1-Ro) and us+w2 (18)
rthermore, a variable is changed like the following formula.
:) '=x(k)-xs y(k) '=y(k)-ys u(k) '=u(k)-us deltax(k) '=x(k) '-x(k-1) ' deltax(k) '=u(k) '-u(k-1) ' (19)
nsequently, ** (17) and (18) formula indicates by the state variable like the following formula.

$$\begin{bmatrix} \Delta x(k+1)' \\ y(k)' \end{bmatrix} = \begin{bmatrix} Po & 0 \\ 1 & 1 \end{bmatrix} \cdot \begin{bmatrix} \Delta x(k)' \\ y(k-1)' \end{bmatrix} + \begin{bmatrix} Ro \cdot (1-Po) \\ 1-Ro \end{bmatrix} \cdot \Delta u(k)' \qquad (20)$$

e following formula will be obtained if the optimal regulator shown in 127 pages of a basic system theory (work sides Katsuhisa Furuta, Corona Publishing Co., Ltd. **) from 114 pages is designed as opposed to the system pressed with a ** (20) formula.
ltau (k) ' =-f1, deltax(k) '-f2, and y(k-1) ' (21)
and f2 are the optimal gain here.

e following formula will be obtained if it returns based on a variable.

$$f\,i\,(k) = \{-f\,1 \cdot \Delta f\,c\,(k+d) - f\,2 \cdot \sum_{j=1}^{k-1} \Delta f\,c\,(j+d) + w\,P\,R\} / \{1 - f\,1 \cdot (1 - R\,o)\} \quad (2\,2)$$

'R is the correction term of a parameter here. Since the value of the future is included in a ** (22) formula about tafc, it replaces using a ** (14) formula.

$$\Delta f\,c\,(k+1) = P \cdot \Delta f\,c\,(k) + (1-R) \cdot \Delta f\,i\,(k-d+2) + (R-P) \cdot \Delta f\,i\,(k-d+1)$$

$$\Delta f\,c\,(k+2) = P \cdot \Delta f\,c\,(k+1) + (1-R) \cdot \Delta f\,i\,(k-d+3) + (R-P) \cdot \Delta f\,i\,(k-d+2)$$

$$\vdots$$

$$\Delta f\,c\,(k+d) = P \cdot \Delta f\,c\,(k+d-1) + (1-R) \cdot \Delta f\,i\,(k-1) + (R-P) \cdot \Delta f\,i\,(k) \quad (2\,3)$$

mely, a ** (14) formula

substituting the above-mentioned formula one by one, it becomes possible to calculate the value of the future about ltafc from a known value. In addition, (22) and (23) formulas constitute the fuel-oil-consumption amendment means 6 of a view 1.

Identification of a parameter Although it came noting that the parameter in the model which expresses the dynamic aracteristics of fuel in the above explanation was known, since it changes according to the operational status of an ernal combustion engine in fact, a parameter is identified serially.

this parameter-identification method, the method (Japanese Patent Application No. 2-193806) which these people oposed, for example can be used.

at is, only a known rate precesses fuel oil consumption and it is from the air-fuel ratio detection value at that time. silon(k) =fcr(k)-fc (k) (24)

carries out, and parameter P-R is determined using a well-known least-squares method so that the following rformance index may take the minimum value.

$$= \sum_{i=k-h}^{i=k} \varepsilon\,(i)^2 \quad (2\,5)$$

e number of time steps used for h= identification here In addition, (24) and (25) formulas constitute the parameter-
ntification means 108 of a view 1.
Execution of control The functional diagram of the control unit constituted by the view 5 according to the above
planation is shown.
at is, in 501, the fuel quantity fcro in a criteria target cylinder calculates based on the internal combustion engine
ational frequency Ne and the pressure-of-induction-pipe force Pm by the method of of (a), (b) or, and (c) of a
plication to a ** (7) formula and 3.
502, amendment fuel quantity deltaf calculates based on the internal combustion engine rotational frequency Ne and
pressure-of-induction-pipe force Pm by the ** (11) formula simultaneously.
e result of an operation in 501 and 502 is added, and it is led to the reverse model 503.
e criteria fuel oil consumption fio injected from an injector 7 based on a ** (12) formula in 503 is determined.
sed on this criteria fuel oil consumption fio, the fuel quantity fcm in a model cylinder calculates from a fuel dynamic
del using a ** (2) formula by 504.
sed on the fuel quantity fc in a cylinder of an actual internal combustion engine, and the fuel quantity fcm in a model
inder, amount of fuel-oil-consumption amendments deltafi is calculated using ** (21) and (22) formulas by 505.
is amount of fuel-oil-consumption amendments deltafi and criteria fuel oil consumption fio calculated by 503 are
led, and it becomes the fuel oil consumption fi actually supplied to an internal combustion engine.
rthermore based on this fuel oil consumption fi and the fuel quantity fc in a cylinder of an internal combustion engine,
parameter of a fuel dynamic model is identified in 505 using ** (24) and (25) formulas.
view 6 is a routine for performing control by this invention, for example, is performed for every stroke.
at is, the detection value Ne required for execution of this routine at Step 601, i.e., an internal combustion engine
ational frequency, the pressure-of-induction-pipe force Pm, and the air-fuel ratio lambda of exhaust gas are read.
Step 602, the fuel quantity fcro in a criteria target cylinder and amendment fuel quantity deltaf calculate.
d in Step 603, it is judged whether an internal combustion engine is in an idling state.
s detectable whether it is in an idling state whether an idle switch 16 is ON. In addition, Step 603 constitutes the
perty state detection means 107 of a view 1.
ually, when it is operational status, a negative judging is carried out at Step 603, and it progresses to Step 604.
Step 604, criteria fuel oil consumption is calculated using a reverse model.
e amount of fuel-injection amendments calculates in Step 605, and it is added with criteria fuel oil consumption in
p 606.
d let the time injector 7 with which the fuel quantity defined at Step 606 in Step 607 is injected be open.
hen an internal combustion engine is in an idling state, in order to carry out an affirmation judging at Step 603 and to
ntify the parameter of a fuel dynamic model, it progresses to Step 608.
Step 608, the regularity rate perturbation of the fuel oil consumption is carried out, and fuel is injected from an
ector 7 at Step 609.
e parameters P and R of a dynamic model are identified at Step 610, and renewal of a parameter is performed at Step
1.
ffect of the Invention]
ange of the property of the fuel-injection control which was excellent in responsibility combining the reverse model
d fuel dynamic model of fuel dynamic characteristics being not only realizable according to the fuel-injection control
it of the internal combustion engine by this invention but an internal combustion engine -- responding -- fuel oil
nsumption -- an amendment -- it becomes possible to increase the stability of control by things

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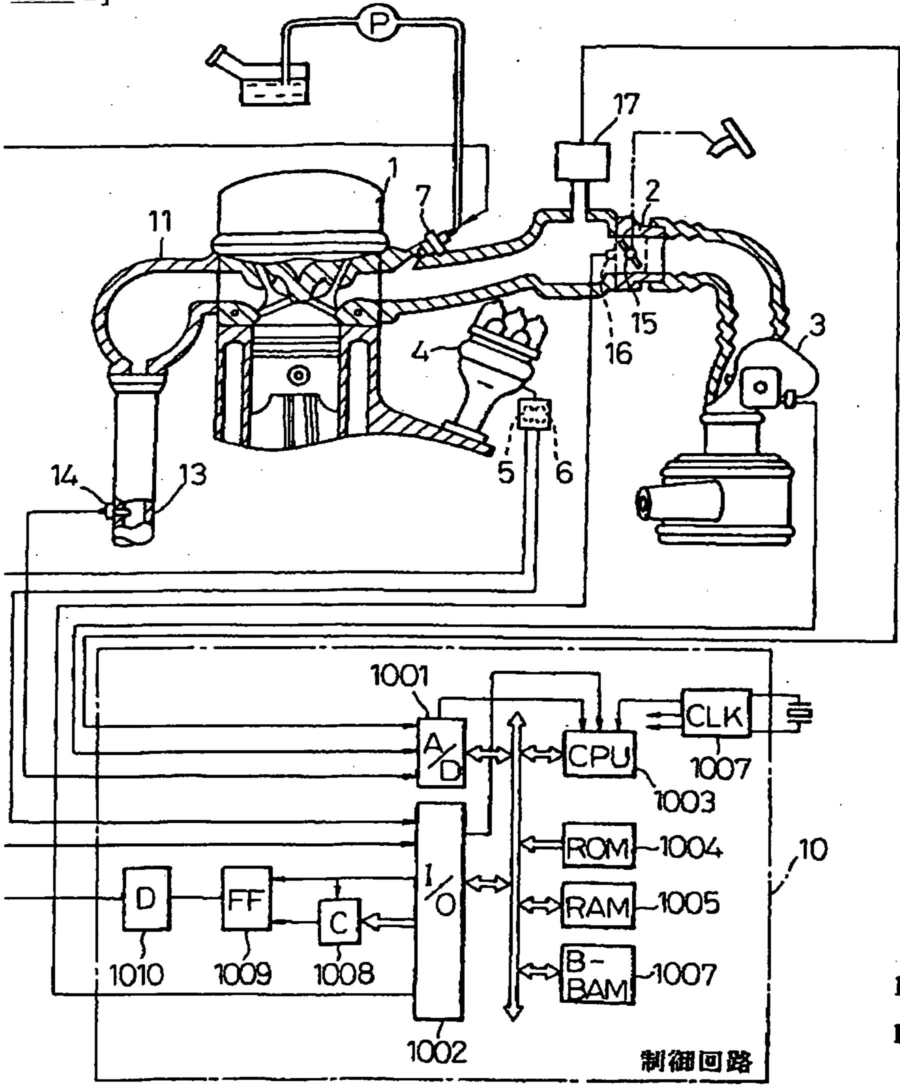
ƐAWINGS

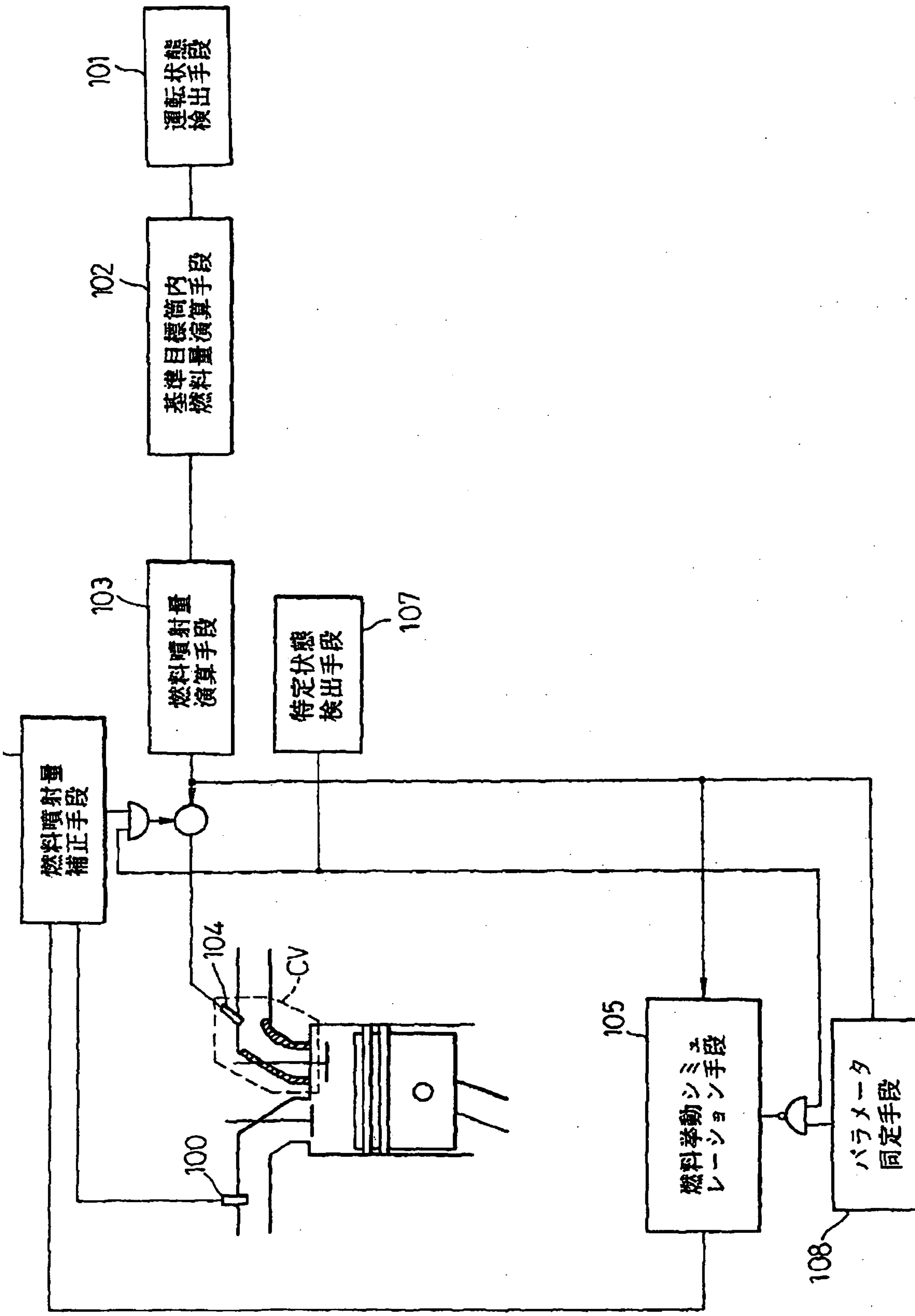
view 2]



1…機関本体
3…エアフロメータ
4…ディストリビュータ
5，6…クランク角センサ
14…空燃比センサ
16…アイドルスイッチ

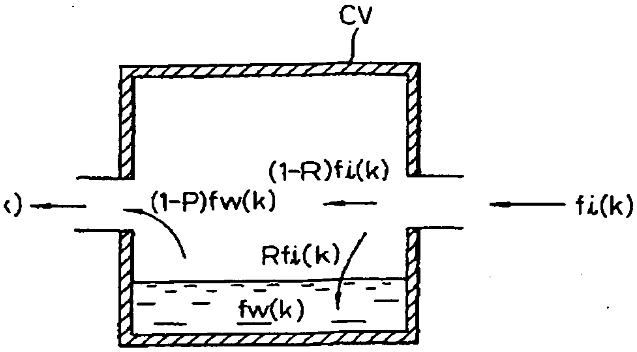
実 施 例

view 1]


101
運転状態
検出手段
102
基準目標筒内
燃料量演算手段
103
燃料噴射量
演算手段
107
特定状態
検出手段
燃料噴射量
補正手段
104
CV
100
105
燃料挙動シミュ
レーション手段
108
パラメータ
同定手段

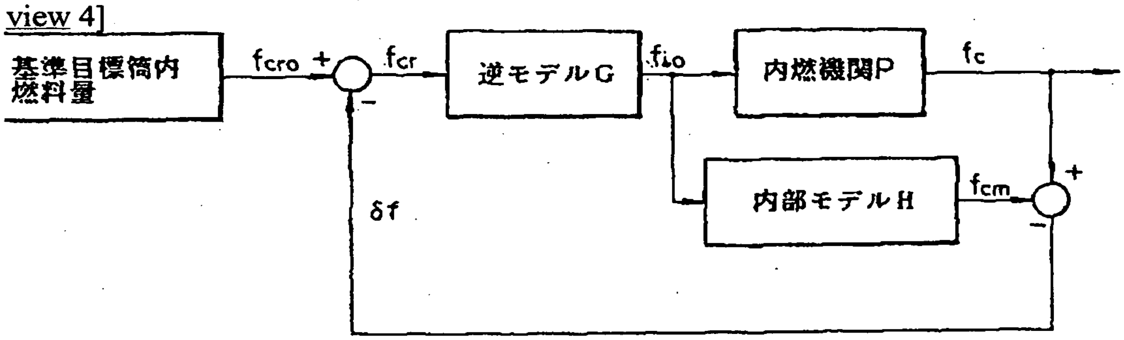
基本構成図

view 3]



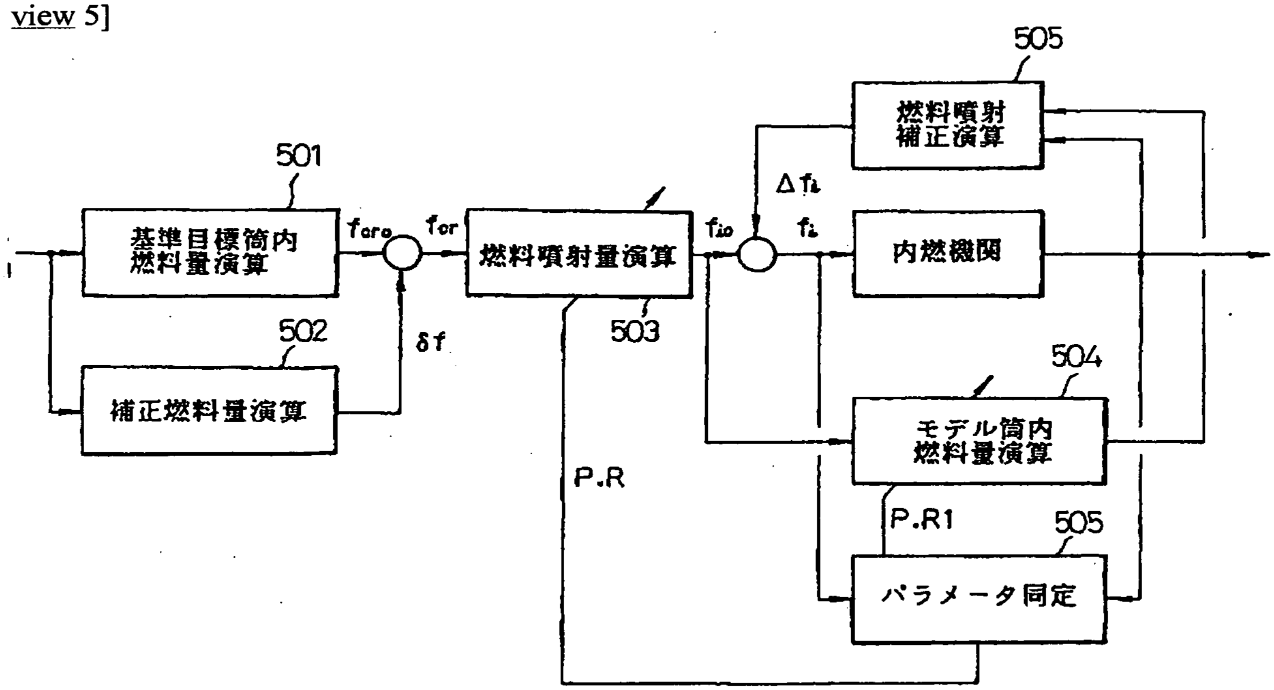
燃料の動的挙動を表すモデル

view 4]



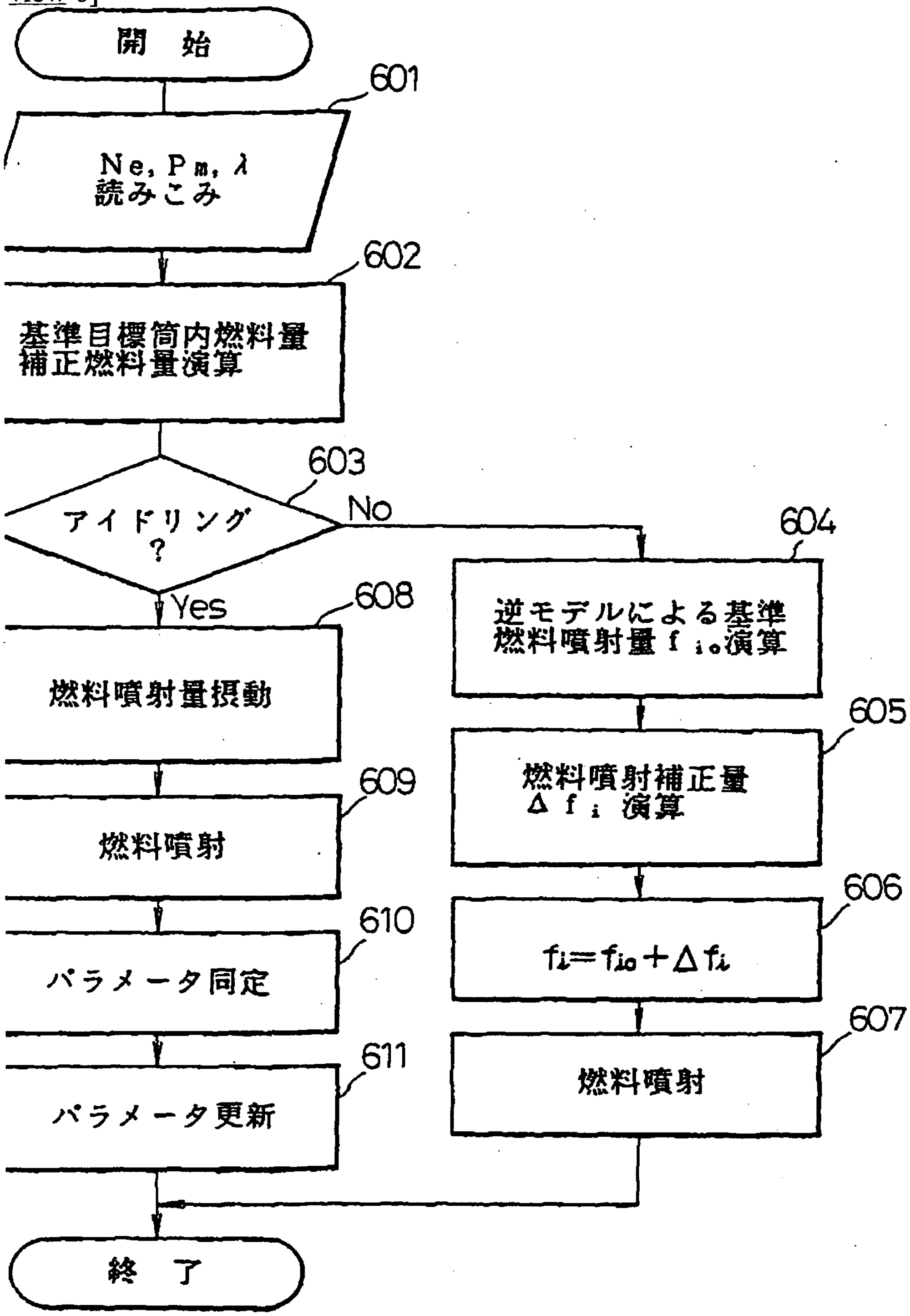
逆モデルと内部モデルによる制御系構成図

view 5]



制 御 機 能 線 図

view 6]



制御演算フローチャート

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